

## METHODS, APPARATUS, MEDIA, AND SIGNALS FOR MANAGING UTILITY USAGE

### BACKGROUND OF THE INVENTION

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#### 1. Field of Invention

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This invention relates to apparatus, methods, media, and signals for managing utility usage, in particular for controlling excessive or non-optimized usage of a utility, controlling a supply of a utility service to a load, facilitating monitoring of subscriber usage of a utility service, and billing a subscriber for utility service usage.

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#### 2. Description of Related Art

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With the increasing prospect of rising natural gas prices, energy shortages, and water shortages looming on the horizon, there is a need for smart management of utility service usage. As national and worldwide energy resources dwindle, there is an increasing need to manage the efficiency of energy and water use. Recent years have seen an increased prevalence of energy blackouts, brownouts, and water restrictions during certain times of the year in order to conserve available resources of energy and water. As we move into the twenty-first century the conservation of energy and water will gain increasing importance, requiring careful management of utilities.

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Many existing systems used to manage utilities do so for control in disaster or abnormal conditions. For example some systems involve shutting off the supply of utilities during an emergency, such as in an earthquake or in response to leak detection or a short circuit. These systems generally monitor for faults or leaks in the utility system and respond by turning off a circuit breaker or shutting off valves and evacuating gases and water in order to prevent further damage to a dwelling or building.

However, in these systems there is no monitoring of utility usage and there is no subsequent controlling of utility supply in response to measurements made while monitoring the utility usage. Underscoring that need is the increased  
5 advantage of minimizing utility usage costs for inefficient use of energy, and the added safety precautions the system would present when utilizing appliances which have not been optimized for energy usage. Moreover, monitoring the usage of utilities would also naturally facilitate the tracking of utility expenditures, and would provide an opportunity to incorporate monitoring and controlling  
10 utilities with a billing process to provide payment for utility usage.

What would be desirable therefore are methods and apparatus which manage usage of a utility service.

## 15 SUMMARY OF THE INVENTION

The present invention addresses the above needs by providing methods, apparatus, media, and signals for managing utility usage.

20 In accordance with one aspect of the invention there is provided a method of controlling usage of a utility including receiving a representation of a utility service usage at a load, receiving and storing a usage range representation, and producing a control signal for use by a utility service interrupter, when the usage is outside of the usage range representation. The control signal is  
25 operable to cause the utility service interrupter to interrupt a supply of the utility service to the load.

The method may include transmitting the control signal to the utility service interrupter, receiving user input specifying the usage range representation  
30 and/or receiving a message from a communications system and extracting the usage range representation from the message according to a network protocol.

The method may also include receiving a plurality of representations of the utility service usage representing the utility service usage at the load, and receiving and storing a plurality of usage range representations.

5       The method may also include producing a derived representation from the plurality of representations of the utility service usage and producing the control signal when the derived representation is outside of the usage range representation. The method may also include comparing the representations of the utility service usage with respective usage range representations and  
10       producing the control signal when a set of representations of the utility service usage is outside of a corresponding set of usage range representations.

15       The method may also include storing the representation of utility service usage, displaying the representation of utility service usage, storing an indication of whether or not the control signal is active, and displaying the indication.

The method may also include transmitting the representation of the utility service usage to a remote location.

20       In accordance with another aspect of the invention there is provided a computer readable medium for providing instruction codes executable by a programmable device, for directing the programmable device to receive a representation of a utility service usage at a load, receive and store a usage range representation, and produce a control signal for use by utility service interrupter, when the  
25       usage is outside of the usage range representation.

30       In accordance with another aspect of the invention, there is provided a computer data signal embodied in a carrier. The computer data signal includes code segments for directing a programmable device to receive a representation of utility service usage at a load, receive and store a usage range representation, and produce a control signal for use by a utility service interrupter, when the usage is outside of the usage range representation.

In accordance with another aspect of the invention there is provided an apparatus for controlling usage of a utility including a communications device operable to receive a representation of a utility service usage at a load and operable to receive a usage range representation, a data storage device operable to store the usage range representation, and a controller, in communication with the communications device and the data storage device. The controller is operable to produce a control signal for use by a utility service interrupter, when the usage is outside of the usage range representation. The control signal is operable to cause the utility service interrupter to interrupt the supply of the utility service to the load.

The controller may further include a control signal generator operable to produce the control signal, or a processor circuit incorporating the control signal generator.

The communications device may be operable to transmit the control signal to the utility service interrupter, to receive user input specifying the usage range representation, to receive a message from a communications system containing the usage range representation, to be extracted from the message by the processor circuit according to a network protocol.

The communications device may be operable to receive a plurality of representations of the utility service usage representing the utility service usage at the load, and operable to receive a plurality of usage range representations. The data storage device may be operable to store the plurality of usage range representations.

The processor circuit may be operable to produce a derived representation from the plurality of representations of the utility service usage, and operable to cause the control signal generator to produce the control signal when the derived representation is outside of the usage range representation. The processor

circuit may also be operable to compare the representations of the utility service usage with respective usage range representations and may be operable to cause the control signal generator to produce the control signal when a set of representations of the utility service usage is outside of a corresponding set of usage range representations.

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The data storage device may be operable to store the representation of utility service usage, or to store an indication of whether or not the control signal is active.

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The apparatus may further include an annunciation device operable to display the representation of the utility service usage, and the processor circuit may be operable to direct the annunciation device to display the indication of whether or not the control signal is active.

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The communications device may also be operable to transmit the representation of utility service usage to a remote location.

In accordance with another aspect of the invention there is provided a method of controlling a supply of a utility service to a load including receiving a control signal indicating that a usage of the utility service at the load is outside of a usage range representation, and interrupting the supply of the utility service to the load in response to the control signal. The control signal may be received at a communications device in communication with a utility service interrupter, and interrupting may include actuating a valve or a switch.

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The method may also include producing a representation of the usage of the utility service by the load, for use by a controller operable to produce the control signal, and transmitting the representation to the controller.

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The method may also include measuring the usage of the utility service by the load to produce a measurement value representing usage of the utility service by the load, and producing the representation from the measurement value.

5 In accordance with another aspect of the invention, there is provided a computer readable medium for providing instruction codes executable by a programmable device, for directing the programmable device to receive a control signal indicating that usage of the utility service at the load is outside of a usage range representation, and to interrupt the supply of the utility service to the load in  
10 response to the control signal.

In accordance with another aspect of the invention, there is provided a computer data signal embodied in a carrier wave, the signal including code segments for directing a programmable device to receive a control signal indicating that a  
15 usage of the utility service at the load is outside of a usage range representation, and to interrupt the supply of the utility service to the load in response to the control signal.

In accordance with another aspect of the invention there is provided an  
20 apparatus for controlling a supply of utility service to a load including a communications device operable to receive a control signal indicating that a usage of the utility service at the load is outside of a usage range representation, and a utility service interrupter, in communication with the communications device. The utility service interrupter is operable to interrupt a  
25 supply of utility service to the load in response to the control signal, and may be operable to actuate a valve or a switch.

The apparatus may also include a processor circuit operable to produce a representation of the usage of a utility service by the load, for use by a controller  
30 operable to produce the control signal. The communications device may be operable to transmit the representation to the controller.

The apparatus may also include a measurement device in communication with the processor circuit. The measurement device may be operable to measure the usage of the utility service by the load to produce a measurement value representing the usage of the utility service by the load, and the processor circuit may be operable to produce the representation from the measurement value.

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In accordance with another aspect of the invention there is provided a method facilitating monitoring of subscriber usage of a utility service including producing a measurement of usage of the utility service at a subscriber location, and transmitting the measurement from the subscriber location to an entity for monitoring the subscriber usage of the utility service.

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In accordance with another aspect of the invention there is provided a computer readable medium for providing instruction codes executable by a programmable device, for directing the programmable device to produce a measurement of usage of the utility service at a subscriber location, and transmit the measurement from the subscriber location to an entity for monitoring the subscriber usage of the utility service.

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In accordance with another aspect of the invention, there is provided a computer data signal embodied in a carrier wave. The signal includes code segments for directing a programmable device to produce a measurement of usage of the utility service at a subscriber location, and transmit the measurement from the subscriber location to an entity for monitoring the subscriber usage of the utility service.

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In accordance with another aspect of the invention, there is provided an apparatus for monitoring usage of a utility service by a subscriber including a utility service measurement device operable to produce a measurement of usage of the utility service at a subscriber location, and a transmitter, in communication with the utility service measurement device, operable to transmit

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the measurement from the subscriber location to an entity for monitoring the subscriber usage of the utility service.

5 In accordance with another aspect of the invention, there is provided a method of billing a subscriber for utility service usage including producing a measurement of usage of the utility service at a location, receiving rate information for the utility service, applying the rate information to the measurement to produce a billing value, and producing a billing signal representing a bill bearing the billing value, for use by an output device at a  
10 subscriber location for producing a bill at the subscriber location.

The method may also include causing the bill to be printed or displayed at the subscriber location in response to the billing signal, or produced at a location designated by the subscriber.  
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The method may also include receiving the rate information at the subscriber location, and applying the rate information at the subscriber location.

The method may also include requesting the rate information from a server, by  
20 establishing a communications connection to a remote server, and transmitting the measurement or a value derived from the measurement to a remote server. The method may also include transmitting utility service usage information to a server.

25 The method may also include producing and storing a plurality of measurements of usage of the utility service, measuring usage of a plurality of utility services, obtaining rate information for at least some of the utility services, applying the rate information to the at least some of the utility services to produce at least some billing values for the at least some utility services, and causing at least  
30 some bills to be produced, bearing the at least some billing values. The method may also include producing the billing signal in response to a request for the bill to be produced.



In accordance with another aspect of the invention there is provide a computer readable medium for providing instruction codes executable by a programmable device and a computer data signal including respective code segments embodied in a carrier wave. The computer readable medium provides instruction codes executable by a programmable device and the computer data signal contains respective code segments for directing a programmable device to produce a measurement of usage of the utility service at a location, to receive rate information from the utility service, to apply the rate information to the measurement to produce a billing value, and to produce a billing signal representing a bill bearing the billing value, for use by an output device at a subscriber location for producing a bill at the subscriber location.

In accordance with another aspect of the invention there is provided an apparatus for billing a subscriber for utility service usage including a utility service measurement device operable to measure the utility service usage at a location, a communications device operable to receive rate information for the utility service, a processor circuit, in communication with the communications device, and operable to apply the rate information to the measurement to produce billing value and to generate a billing signal representing a bill bearing the billing value, for use by an output device at a subscriber location for producing a bill at the subscriber location.

The apparatus may further include an annunciation device responsive to the billing signal for producing the bill bearing the billing value. The annunciation device may further include a printer to print the bill at the location or a printer at a remote location to print the bill at a remote location.

The communications device may further include a receiver operable to receive the rate information at the location. The processor circuit may be operable to apply the rate information at the location.

The communications device may be operable to establish communications with either a server or a remote server to request the rate information from the server or the remote server, and further may include a transmitter operable to transmit either the measurement or a value derived from the measurement to a remote server. The transmitter may be operable to transmit utility service usage information to a server.

The apparatus may further include a data storage device operable to store the measurement of utility service usage.

The apparatus may also include a plurality of utility service measurement devices operable to produce a plurality of measurements of the utility service usage.

The plurality of utility service measurement devices may be operable to measure usage of a plurality of utility services, and the communications device may be in communication with the plurality of the utility service measurements and operable to obtain rate information for at least some of the utility services.

The processor circuit may be operable to apply the rate information to the at least some of the utility service measurements to produce at least some billing values for the at least some utility services.

The annunciation device may be operable to cause at least some bills to be produced, bearing the at least some billing values and may be operable to produce the billing signal in response to a request for the bill to be produced.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

## BRIEF DESCRIPTION OF THE DRAWINGS

In drawings which illustrate embodiments of the invention:

- 5      Figure 1      is a schematic diagram of a system for managing utility usage according to a first embodiment of the invention.
- 10      Figure 2      is a block diagram of a utility management apparatus for controlling a supply of a utility service, as part of the system shown in Figure 1.
- 15      Figure 3      is a flowchart depicting a process effected by a processor circuit of the utility management apparatus shown in Figure 2.
- 20      Figure 4      is a tabular representation of a measurement/status record produced by a processor circuit executing the process shown in Figure 3.
- 25      Figure 5      is a tabular representation of a look-up table read by the processor circuit of the utility management apparatus shown in Figure 2.
- 30      Figure 6      is a tabular representation of a test record recording the status indicators for a plurality of measurement/status records shown in Figure 4.
- 35      Figure 7      is a schematic diagram of a control device of the system shown in Figure 1.
- 40      Figure 8      is a schematic diagram of a control device, according to an alternate embodiment, of the system shown in Figure 1.

Figure 9 is a schematic diagram of a billing system incorporating part of the system shown in Figure 1.

5 Figure 10 is a flowchart depicting a process effected by a processor circuit of the billing system shown in Figure 9.

Figure 11 is a schematic diagram of a bill produced according to the process shown in Figure 10, by the billing system shown in Figure 9.

## 10 DETAILED DESCRIPTION

Referring to Figure 1 a system for managing utility usage, according to a first embodiment of the invention, is shown generally at 10. In this embodiment, the system includes a utility management apparatus 12, a plurality of measurement devices 13, 14, 15, 16, 17, 18, 19, and 21 and a plurality of control devices 26, 28, and 30.

20 The plurality of measurement devices 13, 14, 15, 16, 17, 18, 19, and 21 measure utility usage parameters, such as electrical power, water, and gas used by loads 20, 22, and 24, respectively, for example, and the control devices 26, 28, and 30 may be valves or relays, for example, for controlling the supply of utility services to the respective loads. The load may include appliances connected to a supply of gas, water, or electricity, for example, or other types of utilities.

25 The measurement devices 13, 14, 15, 16, 17, 18, 19, and 21 measure the usage of the utility service by their respective loads to produce a measurement value representing the usage of the utility service by the respective load. The measurement devices 14 and 16, for example, may be  
30 flow meters or flow switches to measure or sense the flow of gas and water to loads 20 and 22, respectively, and measurement devices 13, 15, 17, 19, and 21 may measure the amount of gas, water, heat, and/or other secondary by-

products exhausted from the respective loads. Alternatively, or in addition, measurement device **18** may be operable to measure the electric power consumed by respective electric load **24**, and measurement device **21** may be operable to measure the continuity through the load to determine if the electric load is connected to a supply of utility service. In general, any other measurement devices able to determine the usage of a utility by a load may be used. Moreover, the measurement devices may comprise individual devices or any combination of measurement devices may be grouped together to determine an appropriate measurement of the usage of a utility service by a load.

The measurement value is a representation of the usage of the utility service by the respective loads or may be used to produce such a representation. The representation of utility service usage may be a signal representative of a measurement of flow of water or gas through an appliance, the amount of electric power or thermal energy used by an appliance, for example, or other types of measurements which can be used to determine the usage of a utility service. The representation of utility service usage may represent the usage of a single utility by an appliance, or may represent the usage of a plurality of utilities by various appliances.

The control devices **26**, **28**, and **30** are operable to interrupt a supply of utilities to their respective loads in response to respective control signals. A control signal may be a voltage signal in the 0-5V range, a current signal in the 4-20 mA range, or a computer data signal, for example. Generally, the control signal may be represented by a change in any feature of an electrical signal, for example.

The utility management apparatus **12** includes a communications device **32**, a data storage device **34**, and a utility service controller **36** in communication with the communications device and the data storage device. The utility management apparatus **12** receives, at the communications device **32**, the

representations of utility service usage at loads **20**, **22**, and **24**, from the measurement devices **13**, **14**, **15**, **16**, **17**, **18**, **19**, and **21**, respectively.

5 The communications device **32** is also operable to receive a usage range representation, which serves as a range of values in determining whether there is excessive or non-optimized usage of a utility by a load, and stores the usage range representation in the data storage device **34**. The data storage device **34** may store a single usage range representation pertaining to a single load, or may alternatively store a plurality of usage range representations for various loads. The utility service controller **36** compares the representation of utility service usage at a load to the corresponding usage range representation stored in the data storage device **34**. If the utility service controller **36** determines that the usage of a utility by a particular load **24** is outside of the usage range representation for that load, the utility service controller produces a control signal for use by the control device **30** to interrupt the supply of the utility service to the respective load **24**.

#### Management Apparatus

20 Referring to Figure 2, to achieve the above function, in this embodiment, the utility management apparatus **12** includes a processor circuit shown at **38** as part of the utility service controller **36**. In this embodiment, the processor circuit **38** includes a control signal generator **40** for producing the control signal when the usage is outside of the usage range representation, for use by the control devices **26**, **28**, and **30** shown in Figure 1, to interrupt a supply of the utility service to the respective loads. Alternatively, the control signal generator **40** may be separate from the processor circuit **38**.

30 In this embodiment, the utility service controller **36** also includes a block of instruction codes provided by a processor readable medium accessible by the processor circuit **38**. In this embodiment, the processor readable medium includes a program memory device **42** and a random access memory device

44. Alternatively, the processor readable medium may be a memory device such as a disc drive or CD-ROM, or EPROM, for example, but could alternatively be a communications link to the communications device **32** of the utility management apparatus **12**, where the communications device is operable to communicate with a remote device. The communications link may include the internet, for example.

In the embodiment shown in Figures **1** and **2**, the data storage device **34** is shown as a memory device separate from the utility service controller **36**. Alternatively, the data storage device **34** may be incorporated in the program memory device **42**, the random access memory device **44**, or a CD-ROM, for example. Moreover, the data storage device **34** may be alternatively housed in the utility service controller **36**, as shown in the embodiment in Figure **1**.

Referring to Figure **2**, the communications device **32** is operable to receive from the measurement devices **13**, **14**, **15**, **16**, **17**, **18**, **19**, and **21** the representations of the utility service usage representing the utility service usage at respective loads **20**, **22**, and **24**, and pass the representations to an input port **46** of the utility service controller **36** to be read by the processor circuit **38**. Alternatively, the communications device **32** may store the representations of utility service usage at the data storage device **34**, to be read by the processor circuit **38** of the utility service controller **36** as shown in Figure **1**.

Still referring to Figure **1**, the communications device **32** may also be operable to transmit the representation of utility service usage via a transmitter **55**, such as a modem, for example, over a communications system to a remote location, such as a group of utility service suppliers **53** supplying the utility services or any other entity, for monitoring the usage of the utility service. The transmitter **55** is shown in Figure **1** as separate from the utility management apparatus **12** and the communications device **32**, but alternatively may be part of the communications device of the management apparatus. The

communications system may include a computer network such as the internet **57** or may include a public switched telephone network (PSTN) **52**, for example, or a private network or other communications system configured to deliver messages to contain the representation of the utility service usage.

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The communications device **32** is also operable to receive input specifying the usage range representations of the respective loads. The usage range representation may be a signal derived by a processor in the communications device or other device, from input representing a maximum amount of power, voltage or current allowable to be used by a load **24**, or a maximum amount of water or gas allowable to be used by loads **22** or **20**, respectively. Alternatively, the usage range representation may represent an efficiency rating, a flow rating, a maximum and/or minimum utility service usage amount, a secondary by-product amount, or generally any other criteria which can be used to compare with the measured usage of a utility service by a load to determine if the usage by the load is excessive or not optimized to allow for maximum or efficient performance of an appliance connected to the load.

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The input may be provided by a user from a keyboard **48**, or may be provided in a message from a communications system, which may be the internet **57** or the PSTN **52**, shown in Figure 1. For example, a user managing the utility usage may want to specify the maximum amount of power to be used by a load for a certain time, or may want to change the maximum amount criteria to accommodate changes in the power demand due to holidays or extreme weather or general environmental conditions. Alternatively, the utility service suppliers **53** or other entity may set or change a maximum water usage criteria in response to drought conditions, or may set a total power consumption limit during times of high power demand, for example. Or, for example, the utility service suppliers **53** or other authorities may set different temperature limits for cooling or heating devices in different buildings.

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Alternatively, certain appliances may be equipped with information message transmitting ability, such as ID chips, which can communicate information messages about expected power consumption, for example, to the communications device **32** to provide input specifying the usage range representation. Referring back to Figure **2**, the processor circuit **38** may be operable to extract the usage range representations from the messages and may store the usage range representations in the data storage device **34**.

In the embodiment shown in Figure **2**, the utility service controller **36** is connected to an annunciation device **50**, such as a monitor, television screen, speaker, or printer, for example, which is operable to annunciate by producing sound, printing, or displaying representations of the utility service usage by respective loads. Alternatively, signals produced by the utility service controller **36** for use by the annunciation device **50** may be transmitted to an annunciation device at a remote location, such as at the utility service suppliers **53** or at a location of an owner of a building using the utilities. This provides the user of the utilities, or the one responsible for the usage of the utilities, or the utility suppliers with real-time information relating to utility usage by individual loads or a plurality of loads.

Figure **3** shows a flowchart **60** depicting a process effected by the block of instruction codes stored in the program memory device **42** which cooperates with the processor circuit **38** shown in Figure **2**, to function as the control signal generator **40**. Separate, similar processes are simultaneously executed by the processor circuit **38**, for each load for which usage is monitored. The process is invoked periodically, such as every thirty seconds, to determine if there is an excessive or non-optimized usage of a utility by a load, and measurement of status records for each load are updated to hold current measurements and status of usage of the utility at the load.

Block **62** causes the processor circuit **38** to measure the flow of the utility to the load. To do this the processor circuit **38** may cause the communications

device **32** to transmit a requesting signal to the measurement devices **13, 14, 15, 16, 17, 18, 19, or 21** shown in Figure 1 to produce a measurement value. In response the measurement devices **13, 14, 15, 16, 17, 18, 19, and 21** produce a measurement value representing the usage of the utility service by respective loads, or the measurement value may be provided without the need for a requesting signal. The measurement value may represent the flow of water or gas through an appliance, the amount of electric power or thermal energy used by an appliance, for example, or other types of measurements which can be used to determine the usage of a utility service. For example, if load **20** is used by a gas fireplace device, the amount of usage of the gas utility by the load can be determined from measurement device **14**, which measures the amount of flow of gas into the fireplace device. In addition, the measurement value may represent the amount of heat or carbon dioxide or any other secondary by-product produced by the fireplace device **20** as measured by measurement device **13**. Alternatively, measurement devices **16** and **17** may measure the pressure or temperature of water in two separate sections of a pipe leading to a faucet **22**, respectively, and the measurement value may be the difference in pressure or heat values to determine if the pipe has undesirable transmission capacity.

The measurement value obtained at the I/O port **46** of the processor circuit **38** is then stored at the data storage device in the corresponding measurement/status record, such as the disk drive **34** or memory device **44**, for example. In addition to the measurement value, other information of relevance to the determination of utility usage may be stored. For example, additional information to be stored could include a start period of the measuring process, a time duration of the measuring process, the total consumption used by a load, and identification numbers corresponding to a specific appliance using the utility or specifying the utility supplier. The processor circuit **38** then receives the measurement value at an I/O port **46**. The measurement value as measured by measurement device **14** or **16** may represent the flow of gas or water to loads **20** or **22**, respectively.

Block **64** then causes the processor circuit **38** to determine whether the utility service is supplied to the load. To do this, the processor circuit **38** determines whether the measured flow is non-zero or exceeds minimum threshold criteria and if so the processor circuit determines that utility service is supplied to the respective load.

Further, the processor circuit **38** may be operable to produce a derived representation from a plurality of representations of the utility service usage. The derived representation may represent the efficiency of usage of a load derived from the utility service usage measurements, or may represent the consumption rate or exhaust rate of utility service usage by the load, for example. Alternatively, the derived representation may represent the efficiency of usage of the utility by the load, which, for example, may be determined by using measurement device **15** to measure the temperature change of a room heated by the fireplace device **20** to determine the heat produced, and then dividing the heat produced by the fireplace device by the thermal heat equivalent of gas delivered into the load. In addition, the derived rate may also represent the burning efficiency of gas as determined from measured carbon dioxide value or other secondary by-product value and the amount of gas supplied to the load **20**, for example.

Referring back to Figure 3, once the measurement value is obtained, block **66** directs the processor circuit **38** to compare the representations of the utility service usage with respective usage range representations. If a representation of the utility service usage is within the corresponding usage range representation, block **68** directs the processor circuit **38** to report the representation of utility service usage to the annunciation device **50**, and/or to store the representation in the measurement/status record in the data storage device **34**. In addition, a status indicator indicating that the utility service usage is within the corresponding usage range representation may be stored in the measurement/status record. The processor circuit **38** updates the status

indicator information whenever block **66** has been entered and the representations have been compared. The processor circuit **38** may then direct the annunciation device **50** to display the updated status indicator. The process is then repeated by re-entering block **62** of the flowchart. In addition, the measurement value may also be displayed at the annunciation device **50**. The processor circuit **38** may access other instruction codes stored in the program memory device **42** or other memory device **44**, for example, to provide a graphical display at the annunciation device **50** to provide a user with a presentation of utility usage details, including the measurement values obtained.

If at block **66** it has been determined that a representation of the utility service usage is outside of a corresponding usage range representation, block **68** directs the processor circuit **38** to update the status indicator in the measurement/status record to indicate that the usage range has been exceeded and to store the usage representation and the status indicator and report the status indicator and the representation of utility service usage to the annunciation device **50**. The processor circuit **38** is then directed back to block **62** and the process is repeated. Alternatively, at block **66** the processor circuit **38** may determine if a set or group of a plurality of representations of utility service usage is outside of a corresponding set of usage range representations, and if so, block **68** stores and reports the representation of utility service usage, and updates, stores, and reports the updated status indicator.

If at block **64** it is determined that the utility service is not being supplied to a load, the processor circuit **38** is immediately directed to block **68** to report to the annunciation device **50** and store in the measurement/status record an updated status indicator indicating that no utility service is being drawn from the load.

As stated above, separate similar processes are simultaneously executed by the processor circuit **38** for each load for which utility service usage is measured. Consequently, as a result of executing all of these processes, a plurality of measurement/status records corresponding to respective loads is continually updated to reflect the instantaneous current status of the supply of the utility service to the load.

Referring to Figure 4, an example of a measurement/status record is shown generally at **200** and includes a plurality of measurement fields **202**, usage range fields **204**, status indicator fields **206**, and a control signal field **208**. The measurement fields **202** hold values representing measurements acquired from measurement devices **13**, **14** and **15**, respectively, for example, and may further include a field **203** for holding a derived value, such as energy consumption, computed from measured values. The usage range fields **204** hold values representing usage ranges for each measurement device **13**, **14** and **15** and may include an additional field **205** or fields for derived representations representing energy usage ranges, for example.

The status indicator fields **206** include a primary field **144** indicating whether utility service is delivered to the load, a secondary field **146** indicating whether the usage of the utility is within the corresponding usage range representation, and a response field **148** indicating whether the supply of the utility service to the corresponding load may be interrupted. Each field may take a binary value, a range of integer values indicating, for example, a priority ranking of whether a particular load could be interrupted, or any number of bytes needed to represent the status indicator for a respective load.

In the embodiment shown in Figure 4, the primary field **144** is 0(1) if the supply of utility service is not (is) delivered to the load, the secondary field **146** is 0(1) when the usage of the utility service is outside of (within) the usage range representation, and the response field **148** is 0(1) if the load may not

(may) be interrupted. The response field **148** may be set by a user of the utility, or alternatively a utility service supplier **53**, to make sure that certain loads, such as a furnace for heating or a stove for cooking, may not be interrupted regardless of whether or not the usage is outside of the usage range representation.

The control signal field **208** indicates whether or not a control signal, produced by utility service controller **36** shown in Figure **1**, is active. For example the control signal field **208** is 0(1) if a control signal is not (is) active to cause a control device **26**, **28** or **30** to interrupt a supply of utility service to a corresponding load.

Once the updated measurement/status records resulting from the processes depicted at **60** in Figure **3** are stored in the data storage device **34**, the processor circuit **38** then employs the contents of the status indicator fields **206**, in a look-up table shown generally at **70** in Figure **5**. In this embodiment, the look-up table **70** is stored in the data storage device **34**. Alternatively, the look-up table **70** may be stored in the program memory device **42**, the random access memory device **44**, or other appropriate data storage device for example.

The look-up table **70** includes rows **72** indicating all possible combinations of status indicators **206** associated with respective loads. To use the look-up table **70** the processor circuit **38** produces a test record as shown generally at **220** in Figure **6**, by copying the status indicators **206** for each load into separate fields in a row.

For example, in Figure **6** the test record **220** gives a representation of a particular combination of status indicators **206** for an electric motor load **164**, a gas stove load **170**, a gas fireplace load **168**, a water faucet load **166** and a gas furnace load **172**. For example, the status indicator **164** for the electric motor has a 1 from the primary field **144** indicating that the electric motor is

using electricity supplied by an electric utility, a 1 from the secondary field **146** indicating that the usage of the electric utility is within the corresponding usage range representation, and a 1 from the response field **148** indicating that the load would be interruptible if the utility service usage were outside of the usage range representation. The status indicators **166-172** associated with the remaining loads include a set of values **166** representing the status of a faucet using water utility service. In this embodiment, the set has the value 101 and indicates that the faucet is using water outside of the usage range representation, and that the water service to the faucet may be interrupted. Similarly, sets of values **168** and **170** for the fireplace and the stove, respectively, which use the gas utility service are both 100, indicating that both the fireplace and the stove are using the gas utility service outside of the usage range representation, but the supply of gas is not to be interrupted to these appliances. In addition, a set of values **172** indicates that the gas furnace is using gas within the desired range representation and is not to be shut off.

In this embodiment each particular set of values has three status indicators resulting in eight combinations of status. It will be appreciated that more or less status indicators may be used without loss of generality.

To use the look-up table **70** shown in Figure **5**, the processor circuit **38** searches rows **72** thereof to find a configuration of status indicators **206** matching the configuration in the test record **220** shown in Figure **6**. Once a match is found, the processor circuit **38** locates a corresponding control value **152** which contains a sequence of control fields **154, 156, 158, 160, and 162**, each of which comprises a binary value of 0 or 1 to indicate which, if any, supply of utility service to a corresponding load is to be interrupted. A 0 (1) in a control field indicates that the supply of utility service to the load should (should not) be interrupted. Alternatively, the control fields **154-162** may take on any other values indicating, for example, a priority order of which loads to interrupted, or any other labeling or numbering system readable by the

processor circuit **38** to manage a plurality of utility services at respective loads.

In the embodiments shown in Figures **5** and **6**, if the configuration of status indicators in the test record **220** is 111100100101110, for example, the corresponding control value **152** in the look-up table **70** sequence is 11101. The 1 in the electric motor control field **162**, stove control field **160**, fireplace control field **158**, and furnace control field **154** indicate that the supply of corresponding utility services to those loads are not to be interrupted, while the 0 in the faucet control field **156** indicates that the supply of water to the faucet should be interrupted. As another example, if the configuration of status indicators in the test record is 101100100101110, the control value sequence is 01101, which indicates that the supply of utility service to the stove, fireplace, and furnace are not to be interrupted, while the supply of utility service to the electric motor and faucet is to be interrupted.

The processor circuit **38** causes the control signal generator **40** to produce control signals for use in interrupting the supply or continuing the supply of the utility services to respective loads, in response to the control value sequence which, as seen above, is produced in response to the representation of utility service at the load and the usage range representation.

Referring back to Figure **2**, once the processor circuit **38** has caused the control signal generator **40** to produce the control signals, the processor circuit directs the transmitter **47** to transmit the control signals to the control devices **26**, **28**, and/or **30** shown in Figure **1** to interrupt the supply of the utility to the respective loads **20**, **22**, or **24**. In addition, the control signal field **208** in the measurement/status record **200** shown in Figure **4** is updated to 1 to indicate that the control signal is active. The communication device **32**, or alternatively the processor circuit **38**, reports at the annunciation device **50** that the control signal is active and the supply of service has been interrupted to the corresponding loads.



### Control Devices

In general, each of the control devices includes a communications device and a utility service interrupter. The communications device is operable to receive a control signal and actuate the utility service interrupter to interrupt the supply of the utility service to the load in response to a control signal. The communications device may simply be a screw terminal on a motorized valve to directly use the control signal to actuate the valve, or may be a relay, transistor, microprocessor, computer, or any other device capable of receiving a control signal. The utility service interrupter may include a switch, a relay, a circuit breaker, a valve, a pneumatic device, a hydraulic device, and/or a motorized device, or generally any mechanism that prevents or restricts the passage of a utility service to a respective load.

Referring to Figure 1, for electric loads such as load 24, the control device may be used to simply interrupt the supply of the utility to the load. However, since electrical loads can be replaced relatively easily, it is desirable to be able to restore electrical power to an electrical circuit when the load is changed. To do this, a special control device 30 is used and an enhancement to the flowchart 60 shown in Figure 3 is made.

Referring to Figure 7, the special control device 30 employs a screw terminal as the communication device 39 and a relay 45 as the utility service interrupter 41. In this embodiment the relay 45 has a coil 43 which causes first and second wipers 73 and 74 to move in unison to connect the load 24 to supply contacts 75 and 76 or to sense contacts 77 and 78. In the normal, de-energized state, the load 24 is connected to the supply contacts 75 and 76. When the control signal is received at the coil 43, the load 24 is connected to the sense contacts 77 and 78, which completely isolates the load from the supply for safety, and permits the sense contacts to be used.

The enhancement to the flowchart **69** is shown in dotted lines in Figure **3**. This enhancement is only used for electrical loads **24** along with the control device **30** shown in Figure **7**. The enhancement is invoked after block **66** of the flowchart **60** shown in Figure **3**, when it has been determined that the usage of an electric utility service by the electric load **24** is outside of the corresponding usage range, and a control signal has been sent by the control signal generator **40** to the control device **30** shown in Figure **7**. The control signal energizes the coil **43** to move the wipers **73** and **74** to cause the load **24** to be disconnected from the supply contacts **75** and **76** and connected to the sense contacts **77** and **78**. The load **24** is thus isolated from the utility service supply.

Block **63** then directs the processor circuit **38** to perform a continuity test to test for continuity through the load **24** to detect when a user replaces the load. To do this, the processor circuit **38** directs the utility service controller **36** to send a DC sense signal through the load **24**, using the sense contacts **77** and **78**. The current through the load **24** is sensed by the measurement device **21** which provides a measurement value to the communications device **32** at the utility management apparatus **12** shown in Figure **2**. This measurement value is then stored in the measurement field **202** of the measurement/status record **200** shown in Figure **4**.

Referring to Figures **1**, **2**, and **4**, the processor circuit **38** monitors the measurement field **202** whenever a **1** is stored in the corresponding control signal field **208** to determine whether or not there is a break in continuity. If the electric load **24** is removed from the circuit, then measurement device **21** measures no current and returns a zero value to the utility management apparatus **12**, indicating a break in continuity. This would occur for example, when a user disconnects the defective or inefficient appliance responsible for using electric utility service outside of its usage range and wishes to replace it with a more efficient appliance.

Referring back to Figures 2, 3, 4, and 7, when the load 24 is removed from the circuit, block 65 directs the processor circuit 38 to cause the control signal generator 40 to cease sending the control signal to the control device 30, which de-energizes the coil 43 of the relay 45 to cause the load to be reconnected to the supply contacts 75 and 76 to receive power from the electric utility service. In addition, block 65 directs the processor circuit 38 to reset the control signal field 208 of the measurement/status record 200 to 0, and block 68 is then executed by the processor circuit to store and report the information provided during the process 60. Thus, when the user connects a new load, power from the electric utility supply is immediately available to the load. If the user reconnects the old load, the out-of-range condition will once again be detected and the supply of electric utility service will again be interrupted.

If at block 63 the processor circuit 38 determines that continuity is still established, that is, the offending load remains connected, then the control signal field 208 is unchanged and the coil 43 of the relay 45 remains energized, keeping the load 24 isolated from the utility service supply.

Referring to Figure 8, a control device 79, according to an alternative embodiment of the invention incorporates both measurement and control functions for electrical loads. In this embodiment the control device 79 includes a processor circuit 80, a communications device 81, an I/O device 82 and a utility service interrupter 41 which includes a relay 45 which functions as described in the embodiment shown in Figure 7.

In this embodiment, the communications device 81 facilitates two-way communications between the processor circuit 80 and the utility management apparatus 12 shown in Figure 1. The communications device 81 may form part of a Bluetooth® communications system, for example, or may simply be hardwired to the utility management apparatus 12. The communications device 81 may even be operable to communicate with the utility management

apparatus **12** using the internet or a wireless communication device, for example.

Communications between the processor circuit **80** and the utility management apparatus **12** may involve the utility management apparatus sending messages to the processor circuit, requesting a measurement from the measurement device **18** and/or continuity sensor **21**, or requesting operation or status of the utility service interrupter **41**, and the processor circuit may send a message back to the utility management apparatus with the representation of the measurement or status of the utility service interrupter.

The I/O device **82** is operable to receive signals from the measurement device **18** and a continuity sensor **21**. In addition, the I/O device **82** is operable to provide the continuity sense signal to the load **24** through sense contacts **77** and **78** of the relay **45**, and the coil **43** of the relay is controlled by a signal produced by the I/O device **82**.

The processor circuit **80** is operable to communicate with the I/O device **82** to receive a measure of the usage of the utility service by the load **24**, to produce a measurement value representing the usage of the utility service by the load. The measurement value is received from the measurement device **18**, at the I/O device **82**, and is passed to the processor circuit **80**, which in turn produces a representation of the usage of the utility service by the load **24** from the measurement value. The processor circuit **80** then passes the representation to the communication device **81** for transmission back to the utility management apparatus **12**, shown in Figure 1.

The control device **79** is used in conjunction with the enhancement to the flowchart shown in Figure 3, but instead of the utility service controller **36** sending a control signal directly to the control device, a message including the control signal is sent. This message is interpreted by the processor circuit **80** and, in response, the processor circuit causes the I/O device **82** to issue a

signal to the relay **45** to energize the coil **43** to facilitate continuity sensing. The processor circuit **80** then executes a routine (not shown) which causes it to continuously or periodically transmit a continuity sense measurement to the utility management apparatus **12** for use in conjunction with the flowchart at the utility management apparatus.

In the embodiment shown in figure **1**, the measurement devices **13, 14, 15, 16, 17, 18, 19**, and **21** and the control devices **26, 28**, and **30** are shown as individual measurement and control devices, but some may alternatively be coupled together and sold as a unit in a common housing. Similarly, the utility management apparatus **12** and the utility service controller **36** may be housed in a common housing, as in the embodiment shown in Figure **1**, or may be packaged and sold as separate units.

#### Billing

In accordance with another aspect of the invention, there is provided a billing apparatus for billing a subscriber for utility service usage, shown generally at **90** in Figure **9**. The billing apparatus includes a utility service measurement device **92**, a communications device **94**, and a processor circuit **96**.

The utility service measurement device **92** measures the utility service usage at a location where the utility service is being used. The utility service measurement device **92** may measure usage of a single utility or a plurality of utilities, and further may comprise a single measurement device or a plurality of measurement devices to produce a measurement or a plurality of measurements of utility usage. The utility service measurement devices may be any or all of the measurement devices **13, 14, 15, 16, 17, 18, 19**, or **21** shown in Figure **1**, to measure the usage of gas, water or electricity, or any other utility, for example, or may include utility service inlet devices (not shown)

The communication device **94** is operable to receive rate information for the utility service used as measured by the utility service measurement device **92**. Rate information may be provided by a user of the service at a user interface such as a keyboard **99** for example, or may be provided by utility service suppliers **53**. The rate information may be transmitted via the internet **57**, PSTN **52**, a private network, or any other communications network connecting the rate provider with the communications device **94**, to provide rate information. To do this, the communications device **94** may include a receiver **106** and a transmitter **108**.

The processor circuit **96** is operable to apply the rate information received at the communications device **94** to the measurement produced by the utility service measurement device **92** to produce a billing value and to generate a billing signal representing a bill bearing the billing value. The billing signal may be used by an output device **110** or **118** at a subscriber location for producing the bill at the subscriber location, or may be transmitted to a remote location to generator a bill at a remote location.

To achieve this functionality, a block of instruction codes, stored in the program memory **98**, is executed to start the billing process. The instruction codes may be provided from any computer readable medium, such as a CD-ROM, or downloaded over the internet **57** from a remote server **120**, for example. A flowchart depicting the billing process provided by the block of instruction codes is shown generally at **100** in Figure **10**.

Referring to Figures **9** and **10**, the process is initiated at block **102**, which directs the utility service measurement device **92** to receive a measure of utility service usage at a location. The measurement may be stored by the processor circuit **96** on a data storage device, which may include the program memory **98**, a random access memory **109**, or a disk drive, for example.

Block **104** then directs the communication device **94** to receive rate information from the rate provider. For example, the communications device **94** may establish communications with the server **120**, and cause a rate request to be transmitted to the server. The server **120** may be a remote server, such as a server located at a utility service supplier for example, or may be located at a subscriber's location or any other location that provides the rate information to a subscriber of the utility.

The receiver **106** of the communications device **94** receives the requested rate information from the server **120** and once the rate information is received, block **112** directs the processor circuit **96** to produce the billing value from the measurement values and the rate information for the corresponding utility measured. The processor circuit **96** applies the rate information to the measurement of utility usage to produce the billing value. The billing value may represent costs for utility service usage of a single utility service or a plurality of utility services. The processor circuit **96** may produce the billing value, for example, by multiplying the kilowatt-hours of utility used by a rate per kilowatt-hour, or by multiplying the volume of water or gas used by an appropriate billing rate.

Block **114** then directs the processor circuit **96** to produce a billing signal from the billing value. The billing signal may contain the measurement value of usage of the utility service, a start time period for the measurement, a time duration period of the measurement, and/or identification numbers identifying the user and/or the supplier of the utility service, for example. The billing signal may be a voltage signal in the range of **0-10V**, for example, or may be a message encoded in a TCP/IP protocol operable to be sent over a communications network such as the internet **57**, for example, to a remote location. In this embodiment, the processor circuit **96** transmits the billing signal to an output device such as a monitor **110**, a printer **118**, or any other output device responsive to the billing signal for annunciating the billing value.

An example of a bill produced at the output device **110** or a printer **118** is shown generally at **121** in Figure **11**. In this embodiment, the bill **121** includes various portions identifying the details of utility usage. For example, a utility field **122** identifies the utility supplier, and a user display portion **124** identifies information pertaining to the user of the utilities. The user display portion **124** may contain a site field **126** identifying the location of utility usage, and name **128**, address **130**, and account number **132** fields of a subscriber of the utility service. A consumption field **134** may present the total usage amount of the utility used between dates specified in a duration period field **136**. A rate area **138** may present a rate or a compendium of rates used to calculate the bill amount, and a charge area **140** may present charges for the utility service used. The charge area may list the amount due, due date, and gross charges for utilities used plus additional surcharges, such as tax or connection charges, for example. Other types of display formats may be used which present similar information in any appropriate display format.

While specific embodiments of the invention have been described and illustrated such embodiments should be considered illustrative of the invention only and not as limiting the invention as construed in accordance with the accompanying claims.